VALUATION AND DEMAND FOR U. S. FOREST SERVICE GRAZING IN COLORADO

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A Report Prepared for the Forest Service, USDA
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PREFACE

This report contains a portion of the results of a project funded by the Colorado State University Experiment Station and the United States Forest Service, USDA. The current study is an extension of a study started in 1977 to determine the economic impacts of federal grazing in Colorado. The results of the original study may be found in Impacts of Federal Grazing on the Economy of Colorado by Bartlett, Taylor and McKean (Ausust 1979) and Impacts of Federal Range Forage on Ranches and Regional Economies by Cook, Taylor and Bartlett (Colo. State Univ. Exp. Sta. Bull. 576S, July 1980). This report contains results on the valuation of U.S. Forest Service grazing and compares the values with private lease rates for range forage. Another report [Impacts of Increasing Forest Service Grazing in Colorado by Bartlett and Taylor (1981)] contains the effects of increases in U.S. Forest Service grazing on ranch productivity and regional and State economies.

The authors take all responsibility for the material contained in this report. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect views of the U.S. Forest Service.

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SUMMARY

The demand for U.S. Forest Service (USFS) forage in Colorado was derived for six ranching scenarios. Consideration of three livestock price levels and two possible herd management schemes gave rise to the six scenarios. The six scenarios led to estimates of the competitive market value of USFS forage in a variety of the situations faced by Colorado ranchers.

The competitive market values derived for each scenario are reported in two ways. The first is termed the private lease equivalent. This is an estimate of the competitive market value of USFS forage if the USFS behaved like a private lessor of forage. The 1977 private lease equivalent value for the number of USFS AUMs supplied statewide (about 1.57 million) at average livestock prices from the 1969-1979 cattle cycle is $4.08/AUM when ranch herd size is allowed to vary. The value is $4.69/AUM when ranch herd size is constrained to remain constant.

Government regulations and USFS policy result in the USFS not behaving like private forage lessors. It has been estimated that in 1977 users of federal forage incurred non-fee costs of $1.15/AUM above and beyond the non-fee costs of using forage leased from a private landlord. The second competitive market value, known as the USFS value, takes this into consideration. The USFS value is calculated by subtracting $1.15/AUM from the private least equivalent values. Thus, the 1977 USFS value at the state-wide level of AUM supply for average livestock prices and variable herd size is $2.93/AUM. The value is $3.54/AUM when herd size is constrained to remain constant. In comparison, in 1977 the USFS charged $1.60/AUM in most of Colorado.

Livestock prices have a strong influence on the competitive market value of USFS forage if the rancher is free to expand and contract his herd in response to the price changes. The influence of livestock price is demonstrated by the fact that in 1977 for average livestock prices and variable herd size, the USFS value is $2.93/AUM. However, if demand is derived with the highest livestock prices paid during the 1969-1979 cattle cycle, the USFS value is $8.68/AUM.

Competitive market prices are a useful estimate of the value of USFS forage if it were sold on the open market. However, they are not an accurate measure of the full benefit of USFS forage to society, because they do not include consumer surplus. Willingness to pay values encompass both competitive market value and consumer surplus value. For 1977 at the statewide level of AUM supply, average livestock prices and variable herd size, the willingness to pay is $8.10/AUM. The value is $9.87/AUM when herd size is constrained to remain constant.

INTRODUCTION

Recent legislation and regulations require that the value of goods and services provided by the U.S. Forest Service be determined. Both the Forest and Range Resources Planning Act of 1974 and the National Forest Management Act of 1976 require valuation of goods and services. The regulations for National Forest System Land and Resources Management Planning state that "to the extent possible, demand will be assessed as a price-quantity relationship" (Federal Register 1979, 219.5e2, p. 53986). Grazing is one such output from National Forest lands, but the value of National Forest grazing is not directly priced because federal ownership of the land circumvents market pricing of products from federal lands.

If Forest Service grazing was bought and sold in the marketplace, the price determined by the market would reflect the value of the forage. However, since Forest Service forage is not traded on the open market, it is necessary to use an indirect method to determine its value. Several methods can be used:

1. Market price of alternative forage source,
2. Price paid by users of similar private forage resources,
3. Change in net income of users with and without federal grazing, and
4. Value of the federal grazing permit.

Alternative forage sources, such as hay, supplements and pasture, have little similarity to the grazing offered by the Forest Service. Pastures are lands that produce more forage and are characterized by

more intensive management than most of the National Forest ranges. Because of differences in the nature of the feed sources, it would be difficult to conclude that the value of alternative forage sources would reflect the value of grazing on the National Forests. It would be even more difficult to derive a meaningful price-quantity relationship that is required by Federal regulation.

The amount paid by users of private grazing land similar to National Forest range would reflect the value of the National Forest grazing. This method has been attempted several times, most recently by the U.S. Departments of Agriculture and Interior in 1977. This study was based on a survey, the purpose of which was to determine the "comparable private lease rate." The fair market value of federal grazing would be the comparable private leases rate less the unique non-fee costs associated with using federal rangeland (Bergland and Andrus 1977). The result of the study was a recommended fair market value for federal grazing of $2.38 per AUM[1] in 1978.

Several weaknesses associated with this study are that non-fee costs were assumed to increase at a constant rate over time, value does not change with the quantity and quality of the Federal grazing resource, and the private grazing land was assumed to be comparable to the federal forage resource. Non-fee costs have probably increased at more than the constant rate assumed in the study as more intensive management systems, including grazing systems, have been adopted. While most would agree that higher-quality forage and more forage per unit area should command a higher price, little research has been attempted to relate these range

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[1]An AUM is defined as the amount of feed or forage required by one mature (1000-lb.) cow or equivalent for one month (Range Term Glossary Committee 1974).

characteristics to the value of grazing. If this was done it would imply that value could be determined on an ecosystem-by-ecosystem basis. It is very likely that this will never occur given budgetary and manpower constraints. Finally, most private lease land in Colorado and the West is of higher value than the corresponding public land. This, however, is not as true with rangelands on National Forests, which generally receive higher amounts of precipitation than other federal lands. It should be noted that the total amount of grazing available from private leases is much less than the total amount of grazing available from the National Forests, and to use the value of private grazing to estimate the value for federal grazing assumes that the demand schedules (price-quantity relationship) of each are identical.

The change in net income attributable to the input of an intermediate good is proposed in several sources (U.S. Water Resources Council 1973, Roberts 1963, Gardner 1962). In this approach the value of a unit of grazing would be equal to the value of the marginal product of the grazing after the marginal cost of the grazing has been subtracted out. This is the approach used in this study and is discussed in more detail in the following section.

The final method is essentially an application of the marginal approach. It is argued that the difference between grazing value and the fee plus non-fee costs is represented by the permit value (Roberts 1963, Roberts and Topham 1965, Roberts 1967, Martin and Jeffries 1966). By determining the capitalized value of the permit and non-fee costs, the grazing can be valued. While the method is theoretically correct, it is difficult to obtain an estimate of the permit value, especially with the uncertainty surrounding federal grazing permits that has increased over the last decade.

The purpose of the study was to derive the value of Forest Service grazing at various levels of supply or, simply stated, to derive the demand for Forest Service grazing. Six levels of supply were used in this study. They are 25, 50, 75, 100, 120, and 140 percent of the 1977 supply of USFS forage in Colorado (Table 1).

Because Forest Service grazing is but one of many inputs used by the livestock sector and because the analysis used results in short-run demand schedules, many assumptions were made. Those relating to the short-run are that technology and institutions are fixed, perfect knowledge is available, perfect competition exists in the market, people act rationally, consumers' desires do not change, consumers maximize utility, and producers maximize profit. In addition, the demand derived using the value of the marginal product approach is shaped by the assumptions about the other factors of production and the products themselves. Therefore, in the following sections detailed discussion is presented concerning the assumptions that were made at various points in the study.

Table 1. Number of USFS AUMs at the 6 levels of supply.

	Supply level[1] (1000 AUMs)					
Region	25%	50%	75%	100%	120%	140%
Northeast	38.9	77.8	116.7	155.5	186.7	217.8
Northwest	104.1	208.2	312.3	416.5	499.7	583.0
Southeast	59.8	119.6	179.4	239.2	287.0	334.8
San Luis	64.0	128.0	192.1	256.1	307.3	358.6
Southwest	124.7	249.4	374.0	498.7	598.5	698.2
State Total	391.5	783.0	1,174.5	1,566.0	1,879.2	2,192.4

[1]Percent of 1977 supply of USFS forage in Colorado.

METHODS

Ranch Budget Data

In 1977, 134 of the 2200 ranches which use federal forage in Colorado were surveyed. Additional information concerning each permittee was compiled from Bureau of Land Management and U.S. Forest Service (USFS) grazing allotment records. The 134 ranches randomly selected for the survey were from five regions which had been delineated within the state--the Northwest (I), Northeast (II), Southeast (III), San Luis (IV), and Southwest (V) (Figure 1). The regional divisions were made so that analyses could be conducted on both the regional and state level. For a detailed disucssion of the sampling procedure and region delineation refer to Bartlett et al. (1979).

Sample ranches within each region were grouped into ranch models based on size and type of the livestock inventory. A ranch model

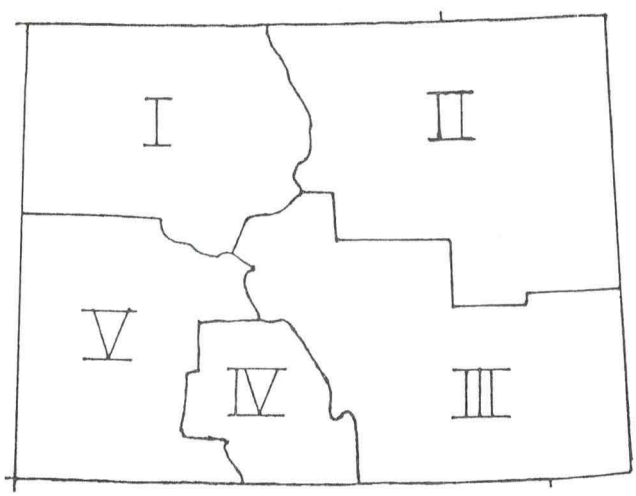

Figure 1. Economic Grazing Regions of Colorado

describes the economic and resource structure of an average ranch within a specific size class. Twenty-five models were constructed to represent the various ranch sizes for each type of livestock in each region. The completed ranch budgets are in Bartlett et al. (1979). The 2200 ranches in Colorado represented by these models have approximately 614,000 cattle and 580,000 sheep. This is about one-third of the cattle and essentially all the sheep in the state (Colorado Crop and Livestock Reporting Service 1980). Size and number of ranches represented by each ranch model are presented in Table 2.

In each model, seasons were delineated to ensure the use of forage by the model in a way which conformed to the seasonal availability shown by the ranch budget. The beginning of each season was defined as (1) spring, starting at the end of winter feeding; (2) summer, starting at average USFS turnout day; (3) fall, starting at average ending date of the USFS grazing season; and (4) winter, beginning at the winter feeding period. The actual dates vary somewhat among regions and between sheep and cattle ranches. For sheep the distinction between fall and winter is obscure. Winter feeding is not often done except to supplement snow-covered forage and at lambing time. Therefore, the fall season as defined became the portion of the early desert wintering season, when no feeding was required.

Determinants of Demand

Demand for USFS forage by a ranch is a function of the conditions under which that ranch operates. A change in any of these conditions will, in general, change the demand. Price and availability of other feeds and forages, livestock prices, and the scheme under which the

Table 2. Distribution and description of the population of federal grazing permittees in Colorado, by ranch model and region.

Region and model	Range of model size (total number of animals)	Number of sample ranches in model	Average ranch size of model				Population represented by the models (adjusted)					
			Breeding cows	Breeding ewes	Total cattle	Total sheep	Number of ranches	Percent of total ranches	Number		Percent of total	
									cattle	sheep	cattle	sheep
Northwest Region (I)		51	439	3607	993	4226	582	100	202,911	306,754	100	100
Cattle Model 1	≤149	6	100		136		226	39	30,736		15	
Cattle Model 2	150-449	10	220		319		153	26	48,807		24	
Cattle Model 3	450-749	4	349		635		44	8	27,940		14	
Cattle Model 4	750-1999	11	621		1251		30	5	37,530		19	
Cattle Model 5	≥2000	6	922		2829		6	1	16,974		8	
Sheep Model 1	0-6000	4		2325		2676	65	11		173,940		57
Both Model 1	≤1399 cattle ≤1750 sheep <1750 AU[1]	5	396	1640	668	1881	54	9	36,072	101,574	18	34
Both Model 2	≥1400 cattle ≥1750 sheep ≥1750 AU	5	420	6600	1213	7810	4	1	4,852	31,240	2	9
Northeast Region (II)		6	231		292	0	165	100	47,889	0	100	0
Cattle Model 1	≤399	4	152		195		111	67	21,645		45	
Cattle Model 2	≥400	2	387		486		54	33	26,244		55	
Southeast Region (III)		17	192	3904	342	4667	497	100	110,159	56,004	100	100
Cattle Model 1	≤199	8	50		73		380	77	27,740		25	
Cattle Model 2	≥200	6	433		759		105	21	79,695		72	
Both Model 1	≤330 cattle ≤12,000 sheep ≤2730 AU	3	90	3904	227	4667	12	2	2,724	56,004	3	100
San Luis Region (IV)		16	395	1049	638	1265	224	100	64,632	75,424	100	100
Cattle Model 1	≤399	6	134		162		144	64	23,328		36	
Cattle Model 2	≥400	5	758		1353		24	11	32,472		51	
Sheep Model 1	650-1250	3		716		692	24	11		16,608		22
Both Model	600-1000 cattle 1500-2500 sheep	2	270	1550	276	1838	32	14	8,832	58,816	13	78
Southwest Region (V)		44	356	1526	713	1852	741	100	188,213	144,302	100	100
Cattle Model 1	≤249	4	126		151		429	58	64,779		34	
Cattle Model 2	250-549	6	311		390		134	18	52,260		28	
Cattle Model 3	550-749	6	314		662		28	4	18,536		10	
Cattle Model 4	≥750	14	599		1290		33	4	42,570		22	
Sheep Model 1	500-1249	3		766		905	36	5		32,580		23
Sheep Model 2	≥1250	4		2150		2635	20	3		52,700		37
Both Model 1	≤219 cattle ≤999 sheep <750 AU	4	91	318	138	355	50	7	6,900	17,750	4	12
Both Model 2	≥220 cattle ≥1000 sheep ≥750 AU	3	60	3067	288	3752	11	1	3,168	41,272	2	28
State, all regions		134	361	2468	735	2976	2209	100	613,804	582,484	100	100

[1]An AU is defined as one mature (1000-lb) cow or the equivalent based upon an average daily forage consumption of 26 lbs dry matter per day (Range Term Glossary Committee 1974).

ranch is managed are three general categories of demand determinants that were considered in this study.

Alternative Feed Supplies

One factor influencing demand is the supply of complementary and supplementary feed and forage inputs. These feeds would be expected to be used in conjunction with increases in present supplies of USFS forage, or to replace USFS forage when availability of this source of forage decreased. This section documents the alternative feed supplies data that was added to the basic ranch models. The alternative feeds were provided to the ranch model in two ways: (1) feed purchases, and (2) improvement of existing ranch production. By adding this information to the ranch model, it was possible to model ranch response to changes in supply of USFS forage. The complementary and supplementary feeds became available in differing amounts and prices, as disucssed below.

Feed Purchases

Additional feed can be purchased from a limited supply within the region or imported, incurring additional transportation costs (Table 3). The amount that can be purchased within each region is dependent upon the crop production of that region. Ranches in the Northeast and Southwest Regions of Colorado can purchase all feed locally, since those regions are principal producers of feed crops. Thus, it was assumed that an unrestricted amount of hay and grain could be purchased at current cost with minimal transportation costs.

The opposite occurs in the Northwest Region, where hay and grain are imported even in normal production years. Therefore, for the Northwest Region all additional grains were imported. Additional purchases

Table 3. Costs and limitations of additional feed purchases.

	Unit	Present Cost	Additional transportation cost ($/ton)										Constraints on local feed purchases as percent of present purchases (%)				
			Northwest		Northeast		Southeast		San Luis		Southwest						
			Reg.[1]	Imp.[3]	Reg.[2]	Imp.	Reg.[2]	Imp.	Reg.[2]	Imp.[4]	Reg.[1]	Imp.[3]	NW	NE	SE	SL	SW
Alfalfa	ton	58	10	24	6	--	6	--	6	--	10	24	10	unlim	unlim	unlim	25
Other Hay	ton	58	10	24	6	--	6	--	6	--	10	24	10	unlim	unlim	unlim	25
Oats (cattle)	ton	112	--	12	3	--	3	--	3	8	6	12	0	unlim	unlim	20	10
Corn (sheep)	ton	103	--	12	3	--	3	--	3	8	6	12	0	unlim	unlim	20	10
Concentrate (32-36% protein)	ton	154	--	12	3	--	3	--	--	8	--	12	0	unlim	unlim	0	0

[1]Assuming a 40-mile transportation radius.

[2]Assuming a 20-mile transportation radius.

[3]Assuming a 200-mile transportation radius.

[4]Assuming a 100-mile transportation radius.

of alfalfa and native hay within the region were limited to 10 percent of present purchases and had a transportation cost of $10/ton assuming a 40-mile radius. Transportation costs of imported feed were calculated for a 200-mile radius. Costs were $18/ton for the first 100 miles and an additional $6/ton for the next hundred miles for both types of hay. The cost for two hundred miles of grain trucking was $12/ton.

In the Southwest Region, Mesa, Delta, and Montrose Counties produce a large amount of hay and grain. So, an additional 25 percent of present hay and an additional 10 percent of present grain purchases were assumed to be locally available. For imported hay and grain the same distances and costs were estimated as for the Northwest Region.

Conejos County in the San Luis Region is the fifth largest hay-producing county in the state, making this area self-sufficient in hay production. Therefore, additional local native hay and alfalfa hay purchases were not limited. Local grain purchases, however, were limited to 40 percent of present consumption. Additional grain purchases were imported from an average radius of 100 miles at costs comparable with those reported for the Northwest and Southwest Regions.

In all regions the use of hay was allowed only in the spring, fall, and winter. Summer feeding was deemed impractical. Concentrates and grains were fed only in the winter because this type of feeding is done to supplement hay rations and native range.

Two alternatives were permitted for additional leased forage. Since there is obviously no large amount of forage to be leased in any region, both alternatives were restrictive. The first alternative allowed a 10 percent increase in leased forage at the current price. To reflect an increased demand for forage the second alternative allowed an

additional 10 percent in leased grazing at half again the current price. Leased forage was available in the spring, summer and fall.

The alternative of transporting sheep to aftermath feed was placed into the sheep models because it is an increasing real-world phenomenon. Sheep are trucked to the east slope from the Northwest and Southwest when desert range has been decimated by drought. The cost of aftermath was 4 cents per head per day and trucking costs round-trip averaged $3/head. Thus, for a four-month grazing season, the total cost per animal unit month (AUM) was $9.75. This feed source was available only in the winter.

Land Improvement Alternatives

The possibilities of improving production on the models' range, pasture, and hayland were considered. Each of these will be discussed individually.

Range. Estimating typical improvements for increasing production from private rangelands in a variety of ecosystems for a model ranch was impossible. No range improvement practice could be applied throughout the variety of ecosystems encompassed by a ranch model. Yet, some improvement must be considered since it is a viable response to a decrease in USFS forage supply. Therefore, the following schedule of range improvements was established: (1) increase available forage by 0.42 AUM/ac on 15% of the range for a cost of $22/ac, (2) increase available forage by 0.42 AUM/ac on 15% of the range for a cost of $32/ac, and (3) increase available forage by 0.42 AUM/ac on 15% of the range for a cost of $42/ac. Each treatment is applied to 15% of a model's private rangeland. Consequently, a total of 45% of the rangeland was considered for some sort of improvement.

The base cost of $22 per acre was the current price paid for range improvement in the ranch survey. The annual increase in carrying capacity of 0.42 AUM/ac was estimated from a survey of sagebrush control projects conducted throughout the West (Neilsen and Hinckley 1975). A 13-year life was estimated for those projects in the study. Using the 9-percent discount rate that was used to amortize portions of the survey data, the annual costs of the three treatments were (1) $7.00/AUM, (2) $10/AUM, and (3) $13.36 AUM. By arbitrarily setting costs, acreages, and productivity at the specified levels, an attempt has been made to model an increasing intensity of improvement needed to attain a certain average increase in production.

Irrigated Pasture. Acreage classified as irrigated pasture differs from hay meadows in that irrigated pasture is grazed and not harvested for hay. This may be due to land characteristics which prevent harvest, water problems, or marginal yields. Research in North Park, Colorado (Ludwick and Rumberg 1977) has shown that yields on irrigated pastures can be increased by fertilization with phosphorous and nitrogen. Three levels of fertilization were documented. They increased production by 1050 lbs/ac, 1850 lbs/ac, and 2280 lbs/ac, respectively. At 1977 prices for fertilizer, these three alternatives cost $3.84/ac, $5.80/ac, and $7.69/ac. In addition, application of the fertilizer cost approximately $2.00/ac. Due to the varying nature of a model's irrigated pasture, only about 30 percent of acreage can be irrigated consistently through the season, making this the only proportion that can be fertilized without risk of fertilizer burning (Table 4).

Hayland. At the Mountain Meadow Research Center in Gunnison, Colorado, four management strategies for hay and grazing from irrigated

Table 4. Irrigated pasture production increases and costs with nitrogen and phosphate fertilization (Ludwick and Rumberg 1977).

	Production increase (AUM/ac)	Cost ($/ac)
Alternative 1	1.125	5.84
Alternative 2	1.98	7.80
Alternative 3	2.44	9.68

meadow hayland were researched (Rumberg 1975). The first management system was a control system "typical" of ranching practices in Gunnison County. The remaining three systems involved varying amounts of fertilization, irrigation, harvesting, seeding, fencing, and supplemental feeding to increase the productivity of hay and grazing (Table 5). These alternatives are most amenable to gently sloping, fairly well-drained soils. Therefore, the area to which this management can be applied was limited to 70 percent of any model's present native hay acreage.

Livestock Prices

A second determinant of demand is livestock selling price. Livestock prices, particularly cattle prices, fluctuate greatly even in the short run. This makes it difficult to determine valid selling prices to use when deriving demand. The demand schedule derived under one year's livestock prices might be significantly different from the schedule derived under the next year's prices. In order to include the range of demand that can occur over a short period of time, the demand was derived

Table 5. Costs and returns for mountain meadow irrigated pasture (Rumberg 1975).

	1977 costs ($/ac)	Returns (unit/ac)	
		Forage (AUMs)	Hay (tons)
Management I	39	1[1]	2.48
Management II	90	0	2.94
Management III	78	1.6[2]	2.34
Management IV	101	4.03[3]	1.756

[1]All grazing was done in the fall.

[2]One-half of the forage (0.8 AUMs) was available in the summer, the remainder in the fall.

[3]0.85 AUMs were available only in the fall, the remainder in the summer.

for three price levels: the low, the mean, and the high livestock prices from the 1969-1979 cattle cycle (Table 6). So, prices from an entire cattle cycle were considered. Prices reported for the month in which the livestock were sold formed the basis for calculations. All prices were adjusted to 1977 prices to coincide with cost data from the ranch survey.

The price data for calves was taken from Colorado Crop and Livestock Reporting Service (1974, 1980). Selling weights for calves, as well as the other classes of livestock, were obtained from the ranch survey data. Calves were sold November 1 and weighed 438 lbs; the yearlings and stockers were sold December 5 weighing 754 lbs. Price data for the yearlings and stockers came from USDA Market News Service (1980) for 600-700 lb choice feeder steers since this was the heaviest weight class

Table 6. Livestock selling prices[1].

	1977 real prices		
	Selling price ($/CWT)		
Livestock class	low	mean	high
Calves	34.90	57.27	81.00
Yearlings and stockers	34.33	52.04	66.00
Cull cows	21.38	32.19	44.73
Lambs	41.63	48.52	58.70
Cull ewes	8.24	14.03	25.08

[1]Source: Colorado Crop and Livestock Reporting Service 1974, 1980), USDA Market News Service (1980).

reported in Colorado. The price data was then adjusted to the 754-lb selling weight by using the average difference in price between 600-700 lb and 700-800 lb choice feeder steers in Omaha. Cull cow prices were taken from Colorado Crop and Livestock Reporting Service (1974, 1980). The culls were sold November 1 and weighted 925 lbs.

Seventy-five percent of the lambs sold weighed 102 lbs and went to slaughter. The other twenty-five percent weighed 85 lbs and were sold as feeder lambs. This gave a weighted average selling weight of 98 lbs for the lambs. Lamb and wool price data was taken from Colorado Crop and Livestock Reporting Service (1974, 1980). The lambs were sold September 15. Price data for cull ewes was taken from the same source. The cull ewes were sold October 15 and weighed 130 lbs.

Herd Management Schemes

At each livestock price level, two herd management possibilities were considered. The first scheme assumed that herd size would change in response to livestock prices and supply of USFS grazing. The second scheme assumed that herd size would remain constant. Demand schedules were derived for both, since each of these responses was deemed possible. Herd management is an endogenous determinant of demand, as opposed to the exogenous factors of feed and livestock prices. The management scheme acts as an internal constraint on how demand can vary.

The "herd-size-vary" scenario is the theoretically predicted response to a change in USFS AUM supply or livestock price. By varying the herd size the rancher is able to maintain the state of profit maximization at which the additional cost of raising one more head of livestock just equals the additional revenue gained from that head of livestock. Such a case is not possible if herd size is forced to remain constant. Cases where marginal cost is less than or exceeds marginal revenue occur. In the former case available profits are foregone and in the latter losses are incurred.

However, there are several reasons ranchers using USFS forage might hold herd size fairly constant in the face of livestock price changes. The rapid and unpredictable fluctuations in cattle prices make it very difficult to adjust herd size quickly enough to maintain profit maximization. Also, there is the danger of guessing the market wrong and ending up with larger losses than if a constant size herd had been maintained. Added to this are the herd management problems associated with frequent buying and selling of brood animals. Not only is it very difficult to maintain a high-quality breeding herd, but also problems are

caused by new livestock being unfamiliar with the terrain of the ranch and USFS allotment.

The regulations concerning retainment of a USFS grazing permit undoubtedly exert a stabilizing influence on herd size also. The USFS regulations state that at least 90% of the number of animals permitted must be grazed each year unless some form of non-use is approved. Either partial non-use or total non-use may be granted, but non-use in any form is not allowed for more than three consecutive years (U.S. Forest Service 1979). These regulations allow moderate flexibility, but ranchers who decrease herd size to the extent that they can no longer fill the permit to 90% capacity must increase herd size again within 3 years or face the possibility of loss of part or all of their grazing permit. The importance of this source of forage becomes evident when it is noted that 44% of the summer forage used by cattle and 53% of the summer forage used by sheep is provided by the permit (Bartlett et al. 1979).

While it is beyond the scope of this study to consider them, it should be recognized that many ranchers have goals in addition to profit maximization. It is possible that these other goals may be better met by maintaining a fairly constant herd size.

The herd-size-constant scenario used the herd size that was reported in the 1977 survey when USFS forage was being supplied and used at approximately the 100% level. The three livestock selling prices and two herd management scenarios generated six demand schedules for each model ranch. Figure 2 summarizes the 6 possibilities.

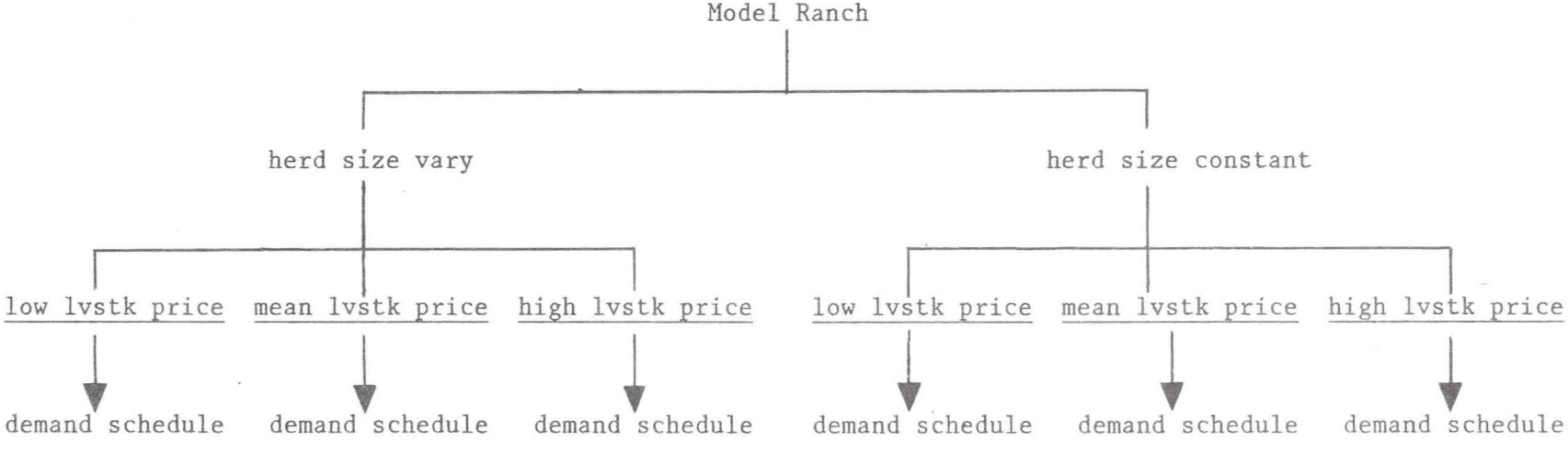

Figure 2. The six demand schedules derived for each ranch model.

Demand Derivation

Demand derived in this study is short-run demand. This means no fixed costs were entered into the models since in the short run fixed costs do not alter demand. It should be noted that operator and family labor were considered to be fixed costs, so no charge was assessed for the use of these inputs. This study does not attempt to make any statement about the long-run demand for USFS forage.

Assumptions

Having discussed the need for several cases to model possible livestock prices and herd management schemes, it is now necessary to discuss some of the assumptions under which demand was derived for the six cases.

Negative Returns to Variable Costs

In the herd-size-constant treatments it was found under certain conditions that gross revenues were less than variable costs. When variable costs are not being recovered, the rational decision is to not operate. Therefore, if the model showed a loss, it was assumed to cease operation; and the number of USFS AUMs demanded was zero. Admittedly, some ranches operate when revenues do not recover variable costs. However, very little is known about the amount of short-run loss ranchers are willing and able to withstand, so demand for USFS AUMs was assumed to be non-existent if a loss was shown in the short run.

Other Enterprises

Some of the ranches had more than a livestock enterprise. For example, cash crop farming was often reported. When deriving the demand for USFS forage, the non-livestock enterprises were not included in the model. Demand was derived based on the livestock enterprise alone. If

the other enterprises had been considered, they could have masked the livestock enterprise when it was not covering variable costs. Returns to variable cost could have been negative for the livestock enterprise, but positive for the ranch as a whole. Since it was established that the livestock enterprise would not operate at a loss, support of the livestock enterprise by another ranch enterprise was not allowed.

Varying Use of Non-Forest Service Feed

In the simplest case, when demand is derived the quantity of one resource is varied while the quantities of the other resources are held constant. In most cases, however, a change in the use of one resource causes a change in the use of other resources. Such is the case with UDFS forage. Instigating a 40% increase in USFS AUMs in the summer but not allowing a corresponding increase in winter feed usage would lead to irrelevant demand schedules in the herd-size-vary cases. A 40% increase in USFS AUMs must be accompanied by a decrease in the use of non-USFS forage in the herd-size-constant cases, since a constant amount of forage is used in those cases.

For all six cases, the price of non-USFS feed inputs was held constant and quantity used was allowed to vary in response to changes in the supply of USFS forage. Most feeds had a maximum amount available as determined by the ranch survey. Protein supplement, grain, alfalfa, and hay imported into a region were available in unlimited quantities. These four feeds were also available in unlimited quantities within the region in some cases (Table 3). For forage from state leases and BLM grazing permits, both the quantities used and prices were held constant at each USFS AUM supply level. Technological conditions were held constant throughout all cases and all supply levels.

Linear Programming

As has been stated, one of the basic assumptions in this study was that ranchers were rational individuals whose goal was to maximize profits. Under any given supply and price for feed and other resources, ranchers would use them in such a way as to maximize profits. Any change in the supply of USFS forage was to be adjusted to in a manner that provided the maximum profit under the new situation. Linear programming was used to ensure that this profit maximization stipulation was met. In this study, the ranch model data and the data on additional sources of feed were put into linear programming format [for a detailed discussion of the matrix and coefficients see Bartlett et al. (1979)]. The program was then used to determine the optimal mix of feed and other resources that would maximize profits at a given supply of USFS AUMs.

In order to derive a demand schedule that showed the six levels of supply, an option in linear programming called parameterization was used. Parameterization allows for computing the response of an optimal solution to changes in quantities that were originially assumed to be constant (Vandermeulen 1971). Parameterization was done by first finding an optimal solution with USFS forage priced at zero. The price of USFS forage was then systematically increased and a new profit maximization solution was determined for each increase. It should be remembered that exactly the same demand schedule for USFS AUMs is obtained by parameterizing either the number or the price of AUMs. Parameterization continued until the USFS AUM price became so high that no USFS AUMs were purchased in the model. At each price, the quantity of AUMs demanded was recorded, yielding a demand schedule.

Demand Schedule Aggregation

Once the demand schedules for a particular case were obtained from all 25 models they were aggregated to determine both regional and state demand under the conditions stipulated for that case. Aggregate demand is the horizontal summation of the individual demand curves. Aggregation techniques are discussed in Appendix A.

RESULTS

Profit Maximization Strategies

In order to interpret and compare the demand curves derived in this study, it is necessary to discuss how the herd-size-constant and herd-size-vary cases are economically efficient. The approach taken plays a major role in determining the demand curves. Each approach will be considered in turn.

Herd Size Constant

The efficiency of the herd-size-constant case is determined by minimizing the cost of running a predetermined number of animals. At each forage price, the least-cost combination of feeds that will maintain the herd size is chosen. As the price of USFS AUMs increases, fewer AUMs are demanded. This is explained by the fact that as the price of the AUMs increases, more and more non-USFS feeds can be purchased at a lower price than the USFS AUM price. Since the total purchase of feed remains constant as the price of USFS forage increases, the amount of USFS forage purchased decreases. Table 7 and Figure 3 show the step-by-step decrease in the purchase of USFS AUMs as price increases. The demand curve shown in the figure is for Northwest Cattle Model 3, a model of moderately large ranches in northwestern Colorado. In general, each step in the demand curve corresponds to a different non-USFS feed or an increased intensity of land management. The length of the step is dependent on the amount of feed available, and the height of the step is dependent on the price of the non-USFS feed.

Table 7. Analysis of the demand curve for Northwest Cattle Model 3 at mean livestock price; herd size constant.

USFS AUM price ($)	Feed source less expensive	AUMs used from this source	Total non-USFS AUMs used	Total USFS AUMs used	Total AUMs used	Point on demand curve in Fig. 3
0.00	- - - - - - - - - initial solution - - - - - - - - - - -		5105	1526	6631	A
3.93	Private irrigated pasture (improvement level 2)	459	5564	1067	6631	B
4.08	Private irrigated pasture (improvement level 3)	107[1]	5671	960	6631	C
4.84	Private hay (improvement level 3)	73[2]	5744	887	6631	D
6.37	Leased range	82	5826	805	6631	E
6.49	Leased range (increased supply, see page 10)	8	5834	797	6631	F
6.99	Private range (improvement level 1)	227[1]	6061	570	6631	G
9.74	Leased range (increased supply, see page 10)	9	6070	561	6631	H
10.16	Private range (improvement level 2)	227[1]	6297	334	6631	I
13.35	Private range (improvement level 3)	227[1]	6524	107	6631	J
16.65	Private hay (improvement level 4)	107[2]	6631	0	6631	K

[1]Reflects the additional forage available due to more intensive management.

[2]Came into use because it provided summer and fall forage as well as hay for winter.

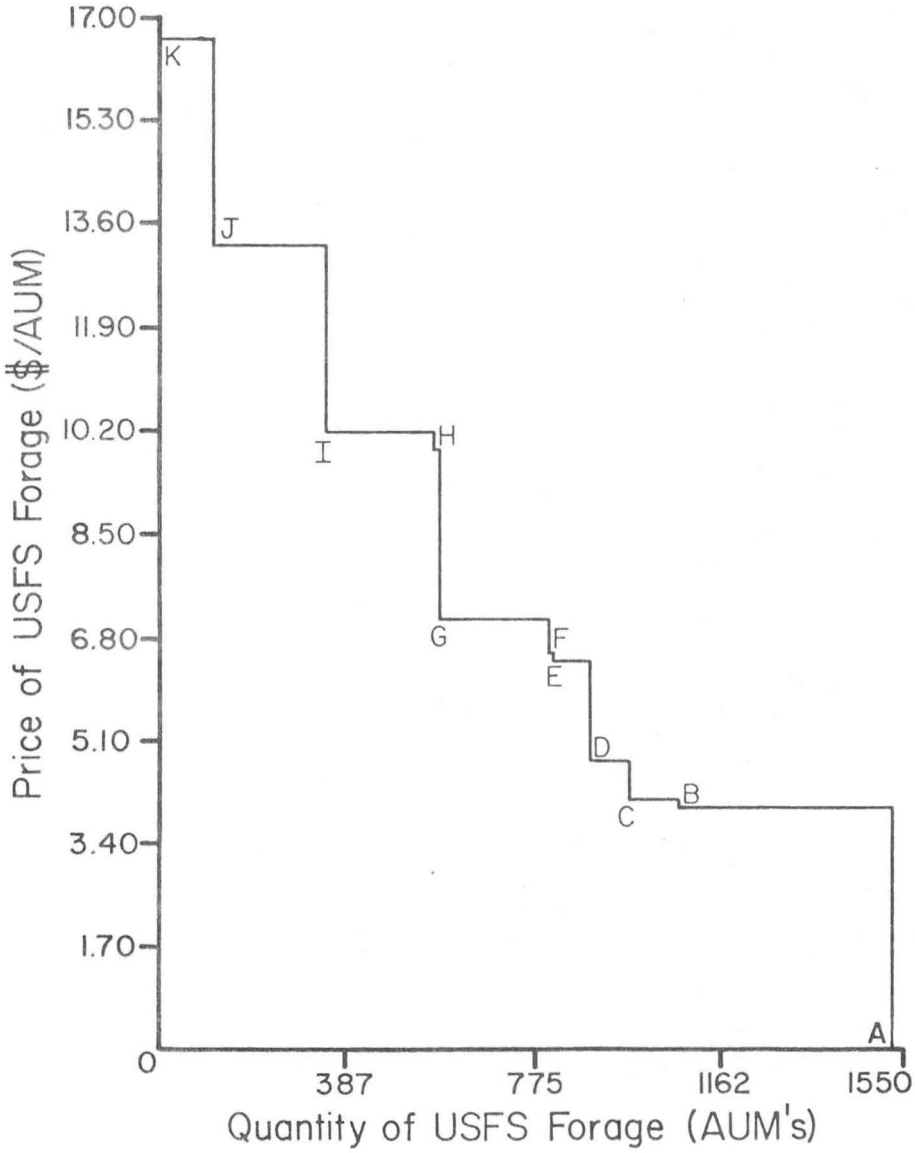

Figure 3. Demand curve for Northwest Cattle Model 3 at mean livestock price, herd size constant.

It is important to note that in the herd-size-constant cases the livestock selling price plays no part in determining the least cost combination of feeds needed to maintain a given size herd. Consequently, livestock selling price plays no part in determining the demand for USFS forage. The demand curve for Northwest Cattle Model 3 under the high livestock selling prices is exactly the same as it is under the low livestock selling prices.

Livestock selling prices do obviously affect a ranch's returns to variable cost. In view of the stated assumption that demand for USFS forage would be reported as zero if the ranch has negative returns to variable costs, it is necessary to discuss net returns more fully. Net returns to variable cost is equal to total revenue minus total variable cost. Total revenue is the price of livestock multiplied by the amount of livestock sold. In a model that has herd size held constant the amount of livestock sold remains constant. So, any change in total revenue is due to a change in price of livestock alone.

Total variable cost is the sum of the cost of all variable inputs. It is convenient to divide these variable inputs into two groups: (1) USFS forage, and (2) all other variable inputs. USFS forage is singled out because it is the only variable input whose cost changes during the demand derivation.

The demand schedules show that there are three general conditions that can separately or together cause total variable costs to exceed total revenue. They are (1) a ranch with relatively high variable costs exclusive of USFS forage costs, (2) high USFS forage costs, and (3) low livestock selling prices. Table 8 shows the variable costs (except for

feed costs and stocker purchasing costs) on an animal unit (AU)[2] basis for each model. It can be seen that variable costs per AU tend to decrease as herd size increases.

The second condition, high USFS forage costs, is actually an extension of the first condition, since USFS forage costs are a variable cost. It was singled out because USFS forage input at a high price can cause a ranch with otherwise relatively low variable costs to have negative returns to variable cost.

Low livestock prices adversely affect the other side of the net revenue equation. They tend to accentuate the problems created by conditions 1 and 2.

As was shown in Table 7 and Figure 3, the demand curve for the herd-size-constant cases is dependent only on the price and availability of non-USFS feeds. However, high variable costs, high USFS costs, and low livestock prices can cause truncation of the reported demand curve. Table 9 shows demand schedules for Northwest Cattle Model 3 for each of the livestock prices when the herd-size is held constant. Note that the demand schedules for the mean and high livestock prices are identical and that the demand schedule under the low price ase has been truncated.

In some models high variable costs and low livestock prices made conditions such that total variable cost exceeded total revenue at even the USFS price of $0.00/AUM. Herd-size-constant models that had no demand for USFS forage at low livestock prices are shown in Table 8. Note that they are mainly small cattle models.

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[2]An AU is defined as one mature (1000-lb) cow or the equivalent based upon an average daily forage consumption of 26 lbs dry matter per day (Range Term Glossary Committee 1974).

Table 8. Size, variable cost, and USFS usage per ranch model (Bartlett et al. 1979).

Ranch model	AUs	VC/AU[1] ($)	Ranches represented by the model	Total AUs represented by the model (1000s)	USFS AUMs used by the model (1977 survey)	Total USFS AUM use represented by the model (1000s)	Total USFS AUM use (1977 survey) represented by the models that did not operate under low livestock prices (1000s)
Northeast Region							
Cattle 1[2]	198	107.80	111	22.0	619	68.7	68.7
Cattle 2	539	74.39	54	29.1	1608	86.8	
Northwest Region							
Cattle 1[2]	131	142.34	226	44.0	305	68.9	68.9
Cattle 2[2]	309	103.31	153	47.3	827	126.5	126.5
Cattle 3	570	73.94	44	25.1	1457	64.1	
Cattle 4[2]	1066	109.12	30	32.0	1278	38.3	38.3
Cattle 5	2045	75.22	6	12.3	1758	10.5	
Sheep 1	458	111.64	65	29.8	892	58.0	
Both 1	860	85.96	54	46.4	618	33.4	
Both 2	2203	74.47	4	8.8	4162	16.6	
Southeast Region							
Cattle 1[2]	71	119.73	380	27.0	85	32.3	32.3
Cattle 2	659	73.33	105	69.2	1771	186.0	
Both 1	930	72.78	12	11.2	1753	21.0	
San Luis Region							
Cattle 1[2]	164	122.93	144	23.6	463	66.7	66.7
Cattle 2[2]	1198	109.38	24	28.8	4279	102.7	102.7
Sheep 1	141	192.91	24	3.4	457	11.0	
Both 1	712	44.71	32	22.8	2368	75.8	
Southwest Region							
Cattle 1[2]	157	123.50	429	67.4	295	126.6	126.6
Cattle 2	401	61.64	134	53.7	1501	201.1	
Cattle 3	539	106.77	28	15.1	1622	45.4	
Cattle 4	1129	79.08	33	37.3	1483	48.9	
Sheep 1	146	209.87	36	5.3	464	16.7	
Sheep 2	421	158.63	20	8.4	1302	26.0	
Both 1	186	66.45	50	9.3	362	18.1	
Both 2	773	107.38	11	8.5	1460	16.1	
State total						1,566.2	630.7

[1]Does not include feed cost and stocker purchase cost.

Table 9. Demand schedules for Northwest Cattle Model 3 when herd size remains constant and livestock prices vary.

	AUMs		
$ per USFS AUM	low live-stock price	mean live-stock price	high live-stock price
0.00	1526	1526	1526
3.93	1067	1067	1067
4.08	960	960	960
4.84	887	887	887
6.37	805	805	805
6.49	797	797	797
6.99	570	570	570
9.74	561	561	561
10.16	0	334	334
13.35	0	107	107
16.65	0	0	0

Herd Size Vary

Efficiency of the herd-size-vary cases was determined by maximizing net returns to variable costs at each USFS forage price. Like the herd-size-constant cases, the demand schedule is the result of substitution of non-USFS feeds as the price of USFS forage rises. However, livestock selling price had a much larger influence on the demand schedule than it did in the herd-size-constant cases. As livestock price rose, marginal revenue rose. This, in turn, allowed marginal costs to rise, meaning the ranch could continue to purchase a given number of USFS AUMs at a higher price. At the same time, the ranch purchased an increased number of non-USFS AUMs and expanded herd size.

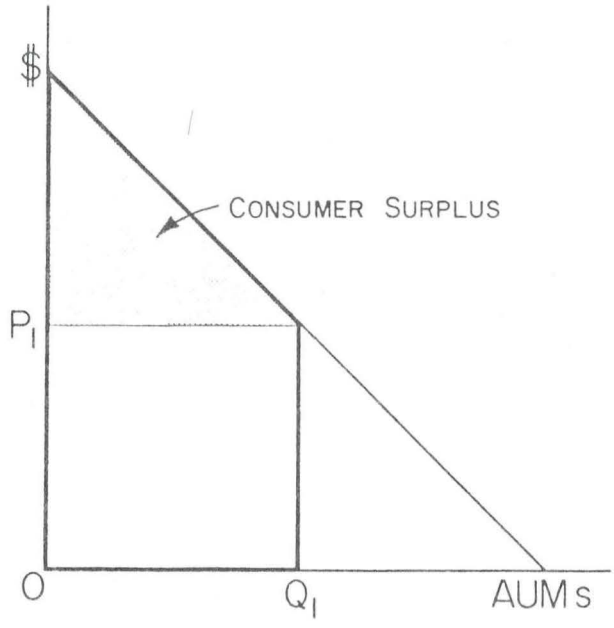
As in the herd-size-constant cases, high variable costs, high USFS AUM costs, and low livestock selling prices separately or together caused the models to operate at reduced levels or not at all. The herd-size-vary models that did not operate at all under low livestock prices were noted in Table 8. They are the same models that did not operate when herd size was held constant.

USFS Forage Values

The primary purpose for deriving demand for USFS forage is to estimate the value of the benefit from using that forage. There are three approaches that might be employed: competitive market value, consumers' surplus, and willingness to pay. Competitive market value and willingness to pay have been estimated in this study and are discussed below.

Competitive Market Value

The competitive market value is the price that the last unit purchased of a good (USFS forage) will command from the consumers of that good. Figure 4 shows that for the last AUM purchased (Q_1), competitive market price is P_1. Two different versions of the competitive market price were estimated in this study. The first estimate was made in an effort to derive values that would be comparable to private lease values if the USFS forage was indeed privately owned. In this effort the variable non-fee costs of using the forage that were related to the location of allotments and animal management were deducted. However, non-fee costs that would not be expected under a private lease were not deducted. The second estimate deducted these costs and represents the competitive market value of USFS forage under federal ownership. The



$$\frac{\text{Area under curve from 0 to } Q_1}{Q_1} = \text{Willingness to pay}$$

Figure 4. The demand curve showing competitive market price, consumers' surplus, and willingness to pay.

first estimate will be referred to as the private lease equivalent value and the second as the USFS value.

Private lease equivalent

In determining the estimates of the private lease equivalent of competitive market price, all variable costs associated with forage use were deducted except for the expenses of maintaining improvements and grazing association fees. It was assumed that the leasor normally would at least maintain fences and water developments. It is of course recognized that the division of costs between leasors and leasees varies greatly from lease to lease. Grazing association fees were not deducted, as these are usually unique to federal grazing use.

Table 10 shows the private lease equivalent values for USFS forage at six levels of supply when herd size was allowed to vary, while

Table 10. Private lease equivalent values ($/AUM) where herd size was allowed to vary for six USFS forage levels and three livestock price levels.

Region and livestock price	USFS forage supply level (percent of 1977 use)					
	25%	50%	75%	100%	120%	140%
NE low	$ 6.00	$ 3.36	$ 0.52	$ 0.52	$ 0.52	$ 0.52
NE mean	13.35	7.16	7.16	6.37	6.07	5.55
NE high	14.40	14.40	14.40	14.19	14.19	13.35
NW low	11.85	3.46	0.74	0.74	0.74	0.74
NW mean	16.49	10.16	5.83	1.86	1.42	0.74
NW high	24.93	14.13	10.93	6.99	5.95	2.06
SE low	1.19	1.19	0.00	0.00	0.00	0.00
SE mean	7.25	6.62	6.23	6.23	6.23	1.19
SE high	13.65	13.35	9.77	9.77	8.92	8.65
SL low	10.16	1.53	1.53	1.53	1.53	1.53
SL mean	14.63	8.96	2.42	1.53	1.53	1.53
SL high	21.09	11.60	9.83	9.58	8.77	6.17
SW low	4.89	3.09	0.33	0.33	0.33	0.33
SW mean	13.35	7.84	6.24	4.82	2.74	0.33
SW high	19.05	13.90	12.89	10.51	9.32	7.01
State low	7.96	0.52	0.33	0.33	0.33	0.33
State mean	14.63	7.35	6.24	4.08	1.42	0.33
State high	21.09	14.13	11.55	9.83	8.65	2.06

Table 11 shows the private lease equivalent values when herd size was held constant. In estimating the values with varying herd size the linear programming models determined the optimal herd size. However, herd sizes determined by the 1977 survey were used in estimating values where herd size was held constant. The optimal herd sizes determined by the linear program at the 100 percent supply level were slightly different than herd sizes reported in the survey. Therefore, the values at 100 percent of current USFS forage supply are slightly different under the two management schemes.

Table 11. Private lease equivalent values ($/AUM) where herd size was held constant for six USFS forage levels and three livestock price levels.

Region and livestock price	USFS forage supply level (percent of 1977 use)					
	25%	50%	75%	100%	120%	140%
NE low	$ 4.87	$ 4.87	$ 0.00	$ 0.00	$ 0.00	$ 0.00
NE mean	13.35	10.16	6.99	6.99	1.66	0.00
NE high	13.35	10.16	6.99	6.99	1.66	0.00
NW low	8.83	4.08	3.42	0.00	0.00	0.00
NW mean	13.45	6.99	6.37	4.84	3.93	3.42
NW high	13.45	9.74	6.37	4.90	3.93	3.42
SE low	3.42	3.42	3.42	3.42	0.00	0.00
SE mean	6.99	6.62	6.37	4.00	3.93	3.42
SE high	6.99	6.62	6.37	4.00	3.93	3.42
SL low	10.16	3.42	0.00	0.00	0.00	0.00
SL mean	10.16	8.83	6.37	4.00	3.42	0.00
SL high	13.71	10.16	6.99	6.08	4.00	3.42
SW low	3.58	3.42	3.42	0.42	0.00	0.00
SW mean	13.35	7.35	6.81	6.08	0.42	0.42
SW high	13.35	8.83	6.81	6.08	0.42	0.42
State low	6.08	3.42	0.42	0.00	0.00	0.00
State mean	12.14	6.99	6.62	4.69	3.58	0.42
State high	13.35	8.07	6.62	4.90	3.93	0.42

For low livestock prices, the returns from livestock did not cover variable costs in eight ranch models, regardless of the management scheme (Table 8). In addition, livestock operation was restricted for many of the other models. This resulted in a low or non-existent aggregate demand under both management schemes at certain levels. In the herd-size-vary scheme aggregate demand was present at all supply levels in all regions with the exception of four of the supply levels in the Southeast Region at low livestock prices. In comparison, the herd-size-constant scheme showed no demand above the 100 percent supply level in

any of the regions at low livestock prices. This difference is explained by the fact that when herd size varied, the more profitable ranches demanded large amounts of forage and counterbalanced the low demand of the other models. Such was not the case when herd size was held constant. With a constant number of animals to feed, a constant amount of feed is needed; therefore, there was no large demand by the more profitable models to counterbalance the low demand of the others.

The values for 100 percent of the 1977 use of USFS forage can be compared to private lease rates. The state average for leasing range determined from the study was $6.38/AUM for cattle and $4.91/AUM for sheep (Bartlett et al. 1979). The private lease equivalent for USFS forage in the state at average livestock prices was $4.08/AUM and $4.69/AUM for the herd size vary and herd size constant, respectively (Tables 10 and 11). Private grazing land lease rates reported in the 1977 study on grazing fees on federal lands ranged from $6.60 to $7.10/AUM in Colorado (Bergland and Andrus 1977, p. 4-13).

The lease rate arrived at in the study ($6.38) was slightly lower than those reported in the 1977 study. However, the rates reported in that study were based on non-irrigated pasture and grazing land. A lease rate of $6.63/AUM for irrigated pasture was estimated from the ranch survey (Bartlett et al. 1979). The slight difference in rates might have been due to the fact that estimates in the 1977 study were based on a sample of all ranches, and thus include many ranches that do not incorporate USFS forages.

USFS values

The USFS value of the competitive market price estimates the value of the USFS forage to the user at varying supply levels. The costs of

allotment maintenance and grazing fees were deducted from the private lease equivalent as the unique cost of using the forage under federal control. The costs were obtained from the Western Livestock Grazing Survey (USDI 1962) as updated by Nielson (U.S. Congress 1978). The survey was conducted for the 17 western states so the data reflects average costs of grazing on federal land rather than being specific to USFS grazing in Colorado. Nielsen's update of prices shows the following costs per AUM: fence maintenance, $0.55; water maintenance, $0.44; and association fees, $0.16. Table 12 shows the USFS values of the competitive market price for both regional and state levels of aggregation when herd size is allowed to vary. Table 13 shows the USFS values under constant herd size conditions. The values are simply the result of the subtraction of $1.15 from the values for the private lease equivalent.

The $1.15 charge for maintenance and association fees is most accurate at the 100% supply level of USFS AUMs. The values shown in Tables 12 and 13 should probably be slightly lower for small levels of USFS forage supply and slightly higher for forage levels above the current level (100%). There is considerable evidence that there are economies of scale expressed in the three costs that make up the $1.15 cost, as well as in other non-fee costs, as allotment size or carrying capacity varies. Grazing costs tend to decrease as the size of allotment increases (Bergland and Andrus 1977). The original ranch budgets showed also that larger ranches usually had lower grazing costs per AUM.

Willingness-to-Pay Values

Competitive market price is a measure of a good's value to the seller. It is not, however, an accurate measure of the value of the

Table 12. USFS values ($/AUM) where herd size was allowed to vary for six USFS forage levels and three livestock price levels.

Region and livestock price	USFS forage supply level (percent of 1977 use)					
	25%	50%	75%	100%	120%	140%
NE low	$ 4.85	$ 2.21	$ 0.00	$ 0.00	$ 0.00	$ 0.00
NE mean	12.20	6.01	6.01	5.22	4.92	4.40
NE high	13.25	13.25	13.25	13.04	13.04	12.20
NW low	10.70	2.31	0.00	0.00	0.00	0.00
NW mean	15.34	9.01	4.68	0.71	0.27	0.00
NW high	23.78	12.98	9.78	5.84	4.80	0.91
SE low	0.04	0.04	0.00	0.00	0.00	0.00
SE mean	6.10	5.47	5.08	5.08	5.08	0.04
SE high	12.50	12.20	8.62	8.62	7.77	7.50
SL low	9.01	0.38	0.38	0.38	0.38	0.38
SL mean	13.48	7.81	1.27	0.38	0.38	0.38
SL high	19.94	10.45	8.63	8.43	7.62	5.02
SW low	3.74	1.94	0.00	0.00	0.00	0.00
SW mean	12.20	6.69	5.09	3.67	1.59	0.00
SW high	17.90	12.75	11.74	9.36	8.17	5.86
State low	6.81	0.00	0.00	0.00	0.00	0.00
State mean	13.48	6.20	5.09	2.93	0.27	0.00
State high	19.94	12.98	10.40	8.68	7.50	0.91

good to society, because it does not consider consumers' surplus. Consumers' surplus is the benefit to the consumers above the price that they pay (Figure 4). The sum of competitive market value and consumers' surplus is the aggregate consumption benefit or total willingness to pay (Marglin 1967). Total willingness to pay is the appropriate measure of the gross benefit from a public program such as the USFS grazing program. Total willingness to pay values for USFS forage under the two management schemes were estimated (Tables 14 and 15). Willingness to pay was calculated for only the USFS values (in which all non-fee costs had been

Table 13. USFS values ($/AUM) where herd size was held constant for six USFS forage levels and three livestock price levels.

Region and livestock price	USFS forage supply level (percent of 1977 use)					
	25%	50%	75%	100%	120%	140%
NE low	$ 3.72	$ 3.72	$ 0.00	$ 0.00	$ 0.00	$ 0.00
NE mean	12.20	9.01	5.84	5.84	0.51	0.00
NE high	12.20	9.01	5.84	5.84	0.51	0.00
NW low	7.68	2.93	2.27	0.00	0.00	0.00
NW mean	12.30	5.84	5.22	3.69	2.78	2.27
NW high	12.30	8.59	5.22	3.75	2.78	2.27
SE low	2.27	2.27	2.27	2.27	0.00	0.00
SE mean	5.84	5.47	5.22	2.85	2.78	2.27
SE high	5.84	5.47	5.22	2.85	2.78	2.27
SL low	9.01	2.27	0.00	0.00	0.00	0.00
SL mean	9.01	7.68	5.22	2.85	2.27	0.00
SL high	12.56	9.01	5.84	4.93	2.85	2.27
SW low	2.43	2.27	2.27	0.00	0.00	0.00
SW mean	12.20	6.20	5.66	4.93	0.00	0.00
SW high	12.20	7.68	5.66	4.93	0.00	0.00
State low	4.93	2.27	0.00	0.00	0.00	0.00
State mean	10.99	5.84	5.47	3.54	2.43	0.00
State high	12.20	6.92	5.47	3.75	2.78	0.00

considered). The private lease equivalent values were estimated only for the competitive market prices in order to compare USFS forage with the private range forage market.

The willingness to pay values are of course higher than the competitive market values because consumers' surplus has been included. The difference between willingness to pay and competitive market values decreases as demand becomes more elastic because consumers' surplus decreases. In such cases the market price will give a good estimate of social value (Sinden and Worrell 1979). However, when demand is

Table 14. USFS values ($/AUM) in terms of total willingness to pay where herd size is allowed to vary for six USFS forage levels and three livestock price levels.

Region and livestock price	USFS forage supply level (percent of 1977 use)					
	25%	50%	75%	100%	120%	140%
NE low	$ 4.96	$ 4.74	$ 3.15	$ 2.22	$ 1.76	$ 1.43
NE mean	14.67	11.34	9.62	7.66	8.09	7.63
NE high	23.97	18.34	16.46	15.52	15.29	14.68
NW low	15.27	10.48	6.89	5.11	4.26	3.66
NW mean	22.54	17.56	13.57	10.93	9.12	7.77
NW high	35.50	27.58	20.83	17.84	15.61	13.68
SE low	9.17	4.70	0.00	0.00	0.00	0.00
SE mean	13.18	9.43	8.03	7.33	6.98	6.09
SE high	20.49	16.09	13.93	12.48	11.80	11.27
SL low	12.10	9.29	6.25	4.74	3.97	3.43
SL mean	14.43	13.23	10.51	7.93	6.63	5.71
SL high	20.38	19.11	15.97	14.09	13.05	12.03
SW low	8.11	5.45	3.53	2.44	1.89	1.50
SW mean	15.27	12.50	10.31	8.83	7.71	6.85
SW high	24.45	19.74	17.43	15.61	14.32	13.20
State low	10.39	6.30	3.94	2.76	2.17	1.74
State mean	15.05	11.84	9.56	8.10	6.85	5.77
State high	25.49	20.48	17.35	15.38	14.17	12.73

relatively inelastic, as in this study, consumers' surplus is large and must be included to estimate value to society.

Table 15. USFS forage values ($/AUM) in terms of total willingness to pay where herd size is constant for six USFS forage levels and three livestock price levels.

Region and livestock price	USFS forage supply level (percent of 1977 use)					
	25%	50%	75%	100%	120%	140%
NE low	$ 3.74	$ 3.74	$ 0.00	$ 0.00	$ 0.00	$ 0.00
NE mean	26.96	18.54	15.19	12.94	11.44	0.00
NE high	27.23	18.67	15.28	13.01	11.47	0.00
NW low	11.33	7.90	6.02	0.00	0.00	0.00
NW mean	18.99	13.93	11.07	9.30	8.22	7.39
NW high	18.99	13.93	11.26	9.72	8.64	7.78
SE low	7.12	4.55	3.64	3.19	0.00	0.00
SE mean	10.56	8.12	7.16	6.23	5.68	5.15
SE high	10.56	8.12	7.16	6.27	5.68	5.49
SL low	11.18	8.26	0.00	0.00	0.00	0.00
SL mean	11.22	9.65	8.29	7.21	6.39	0.00
SL high	13.51	12.20	10.53	9.22	8.34	7.53
SW low	5.79	3.89	3.24	2.44	0.00	0.00
SW mean	26.14	16.70	13.02	11.18	9.86	8.38
SW high	26.14	17.46	13.50	11.47	10.00	8.50
State low	8.46	5.64	3.94	0.00	0.00	0.00
State mean	21.10	14.73	11.63	9.87	8.63	7.32
State high	21.10	14.78	11.72	9.93	8.65	7.39

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APPENDIX A

It has been recognized in this study that an increase in USFS AUMs to 140% of 1977 levels would be an average increase for the state. USFS AUM supply increases would be greater than 40% in some areas and less than 40% in others. Even so, cases arose during demand derivation in which a ranch demanded far more USFS AUMs than the USFS could be expected to provide. Individual demand schedules that showed demand for unrealistically large amounts of AUMs created distortions in aggregate demand schedules, as shown in Figure 5. In Figure 5A ranch X demands a large number of USFS AUMs at price P_1 while ranch Y demands only small amounts even at low prices. When these two demand curves are summed horizontally in Figure 5B, a distorted curve results. The distance between points A and B is dependent on the number of AUMs that can be supplied to Ranch X. For this reason it was necessary to limit the number of AUMs supplied to Ranch X to a justifiable number. The ranch's 140% supply level was chosen as this number since it was the only available estimate of the potential for AUM increase. When Ranch X is restricted to its 140% level, as in Figure 5C, the aggregate demand curve becomes that shown in Figure 5D.

Though this approach was needed to eliminate large-scale distortion, it did not produce entirely satisfactory results. Figures 5C and 5D show that each ranch must demand its 140% supply level if there is to be demand registered for the aggregate 140% level. Not surprisingly, instances were common (especially at the higher levels of supply) in which no aggregate demand was registered. This lack of aggregate demand

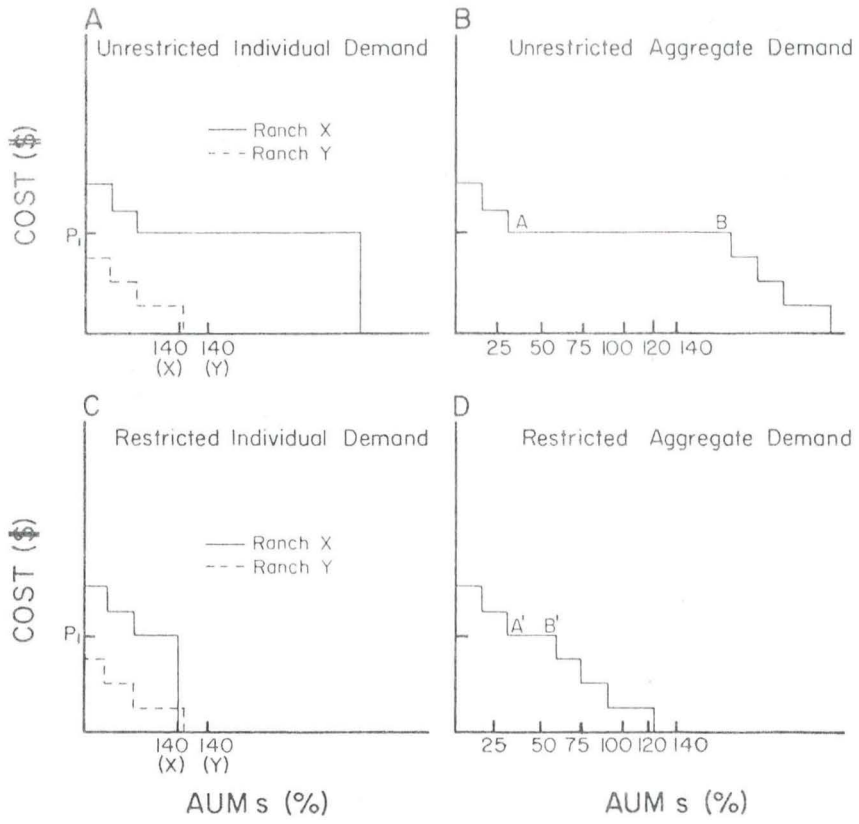

Figure 5. Effect of restrictions in USFS AUM supply on the aggregate demand curve.

is rather misleading. It is probable that if ranches had been allowed to demand slightly more than their 140% level, aggregate demand would have been expressed without letting individual ranches demand an unrealistic number of AUMs.

Therefore, demand aggregation was conducted with individual ranch demand restricted (Figures 5C and 5D), and then demand aggregation was conducted with individual ranch demand unrestricted. If the unrestricted aggregation showed demand at levels that the restricted aggregation did not show, demand at these levels was assumed to exist. The AUM prices obtained from an unrestricted aggregation are of little use, as was shown in Figure 5B. Therefore, the AUM prices obtained from the restricted aggregation were used as a guideline for determining values of the points obtained from unrestricted aggregation. Thus, in Figure 5D, the same AUM price is recorded for both the 120% and 140% supply levels. Tables 16 and 17 show the data points that were obtained by unrestricted aggregation.

Table 16. USFS AUM values (cf. Table 12) that were obtained by unrestricted aggregation (underlined), herd size vary.

Region and livestock price	USFS forage supply level (percent of 1977 use)					
	25%	50%	75%	100%	120%	140%
NE low	$ 4.85	$ 2.21	$ 0.00	$ 0.00	$ 0.00	$ 0.00
NE mean	12.20	6.01	6.01	5.22	4.92	4.40
NE high	13.25	13.25	13.25	13.04	13.04	12.20
NW low	10.70	2.31	0.00	0.00	0.00	0.00
NW mean	15.43	9.01	4.68	0.71	0.27	0.00
NW high	23.78	12.98	9.78	5.84	4.80	0.91
SE low	0.04	0.04	0.00	0.00	0.00	0.00
SE mean	6.10	5.47	5.08	5.08	5.08	0.04
SE high	12.50	12.20	8.62	8.62	7.77	7.50
SL low	9.01	0.38	0.38	0.38	0.38	0.38
SL mean	13.48	7.81	1.27	0.38	0.38	0.38
SL high	19.94	10.45	8.63	8.43	7.62	5.02
SW low	3.74	1.94	0.00	0.00	0.00	0.00
SW mean	12.20	6.69	5.09	3.67	1.59	0.00
SW high	17.90	12.75	11.74	9.36	8.17	5.86
State low	6.81	0.00	0.00	0.00	0.00	0.00
State mean	13.48	6.20	5.09	2.93	0.27	0.00
State high	19.94	12.98	10.40	8.68	7.50	0.91

Table 17. USFS AUM values (cf. Table 13) that were obtained by unrestricted aggregation (underlined), herd size constant.

Region and livestock price	USFS forage supply level (percent of 1977 use)					
	25%	50%	75%	100%	120%	140%
NE low	$ 3.72	$ 3.72	$ 0.00	$ 0.00	$ 0.00	$ 0.00
NE mean	12.20	9.01	5.84	5.84	0.51	0.00
NE high	12.20	9.01	5.84	5.84	0.51	0.00
NW low	7.68	2.93	2.27	0.00	0.00	0.00
NW mean	12.30	5.84	5.22	3.69	2.78	2.27
NW high	12.30	8.59	5.22	3.75	2.78	2.27
SE low	2.27	2.27	2.27	2.27	0.00	0.00
SE mean	5.84	5.47	5.22	2.85	2.78	2.27
SE high	5.84	5.47	5.22	2.85	2.78	2.27
SL low	9.01	2.27	0.00	0.00	0.00	0.00
SL mean	9.01	7.68	5.22	2.85	2.27	0.00
SL high	12.56	9.01	5.84	4.93	2.85	2.27
SW low	2.43	2.27	2.27	0.00	0.00	0.00
SW mean	12.20	6.20	5.66	4.93	0.00	0.00
SW high	12.20	7.68	5.66	4.93	0.00	0.00
State low	4.93	2.27	0.00	0.00	0.00	0.00
State mean	10.99	5.84	5.47	3.54	2.43	0.00
State high	12.20	6.92	5.47	3.75	2.78	0.00

APPENDIX B

The main body of this report presented the derived values for six discrete levels of USFS forage supply under a variety of scenarios. The purpose of this appendix is to present the complete demand curves and to compare the curves from the different scenarios. The majority of the comparisons will be made at the state level with regional comparisons only briefly mentioned.

Comparisons of Livestock Price Levels

Herd Size Vary: Figure 6 shows the state demand curves for three livestock price levels when herd size is allowed to vary. These curves, as well as the other curves in this appendix are from USFS values (as defined in the report) and do not include the data points that were obtained by the second aggregation (Appendix A). The curves show an increase in the price of the product causes demand to shift to the right. This increase in demand for USFS forage is accompanied by an increase in herd size.

Herd Size Constant: Figure 7 shows the state demand curves for the herd size constant scheme. The curves for the average and the high livestock prices are identical except as shown by the dotted line. In order to interpret these curves it is necessary to review the change in net income method which was used in this study to determine USFS forage value. From the discussion of the method in the introduction to this report we see that the marginal value of an AUM of USFS forage can be calculated as follows:

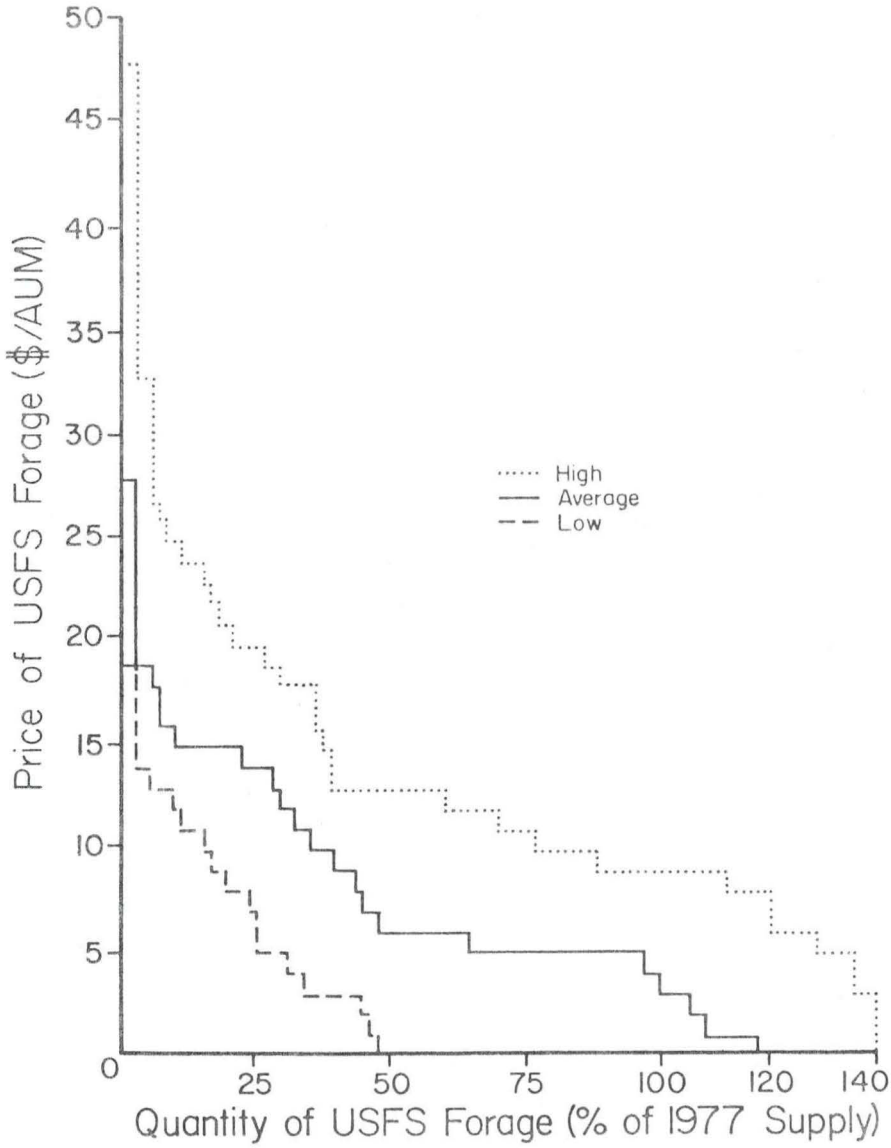

Figure 6. Aggregated USFS forage demand for Colorado for three livestock price levels and varying herd size.

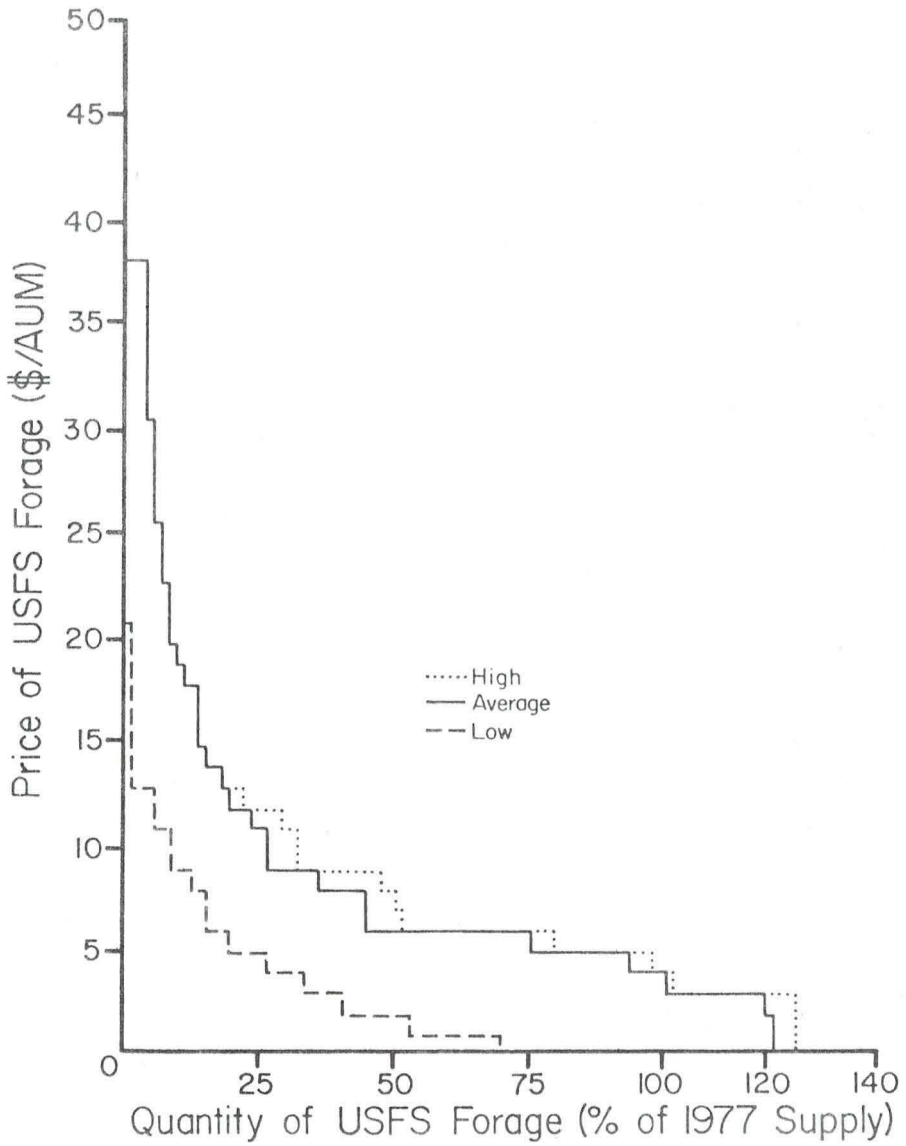

Figure 7. Aggregated USFS forage demand for Colorado for three livestock price levels and constant herd size.

Value of an additional AUM = (Δ livestock sold $\times$ livestock price)
$-\Delta$ variable cost.

However, when herd size is held constant, Δ livestock sold = 0

So, value of an additional AUM = $-\Delta$ variable cost

In the ranch models, all variable costs are either allocated to feeds or to the animals. Feeds' variable costs and availability do not change when livestock prices change. So, when herd size is held constant, the changes in variable cost are totally a result of changes in the mixture of feeds used. Thus, the change in net income method of demand derivation simplifies to a classic least cost ration problem. It closely resembles the market price of alternative forage sources method discussed in the introduction to this report.

The demand schedule for USFS forage is derived by substituting USFS forage for other forages and then calculating $-\Delta$ variable cost. Starting at the point where there is no USFS forage in the ration, the most expensive feeds are replaced by USFS forage first, followed by the less expensive feeds. This means that the $-\Delta$ variable cost is largest for the first USFS AUM substituted into the ration and subsequently decreases.

If livestock price plays no part in determining the demand schedule why are not all three state demand schedules identical? They would be if it were not for the ranches which experience negative returns to variable costs and thus, in the assumptions of this study, cease operation. This cesession of operation reduces aggregate demand and is the reason the state demand curve for low livestock prices is lower than the other two curves (Figure 7). At both average and high livestock prices, almost all ranches operate, so the state demand curves are nearly identical.

Comparison of Herd Management Schemes

When comparing the herd size vary and herd size constant schemes at the same livestock price, the herd size vary scheme would be expected to exhibit a more elastic demand for USFS forage. Under this scheme ranches have the flexibility to adjust animal numbers as well as the mix of feeds used. Many of the models do indeed show a more elastic demand curve for vary than constant as exemplified by Figure 8, which shows the demand curves at average livestock price for a mid-sized model ranch in southwestern Colorado. The vary scheme uses more USFS AUMs than the constant scheme when USFS prices are low and fewer than the constant scheme when USFS prices are high.

There are, however, several cases when this expected difference is not seen. In some models the herd size vary scheme uses fewer USFS AUMs than the constant scheme at all USFS prices. This case is seen most often at low livestock prices. Figure 9 shows demand at low livestock prices for Northwest cattle model 3. Conversely, at times the vary scheme uses more USFS forage than the constant treatment at all USFS prices. This is seen most often when livestock prices are high as in the case of Figure 10. This figure is for a large model ranch in southeastern Colorado.

The existence of these two cases, coupled with the fact that the demand schedules for different models have different X and Y intercepts, led to similar elasticities for the state aggregated curves at each livestock price level (Figures 11, 12, and 13). Only the high livestock price shows herd size vary more elastic than herd size constant; and then only weakly so.

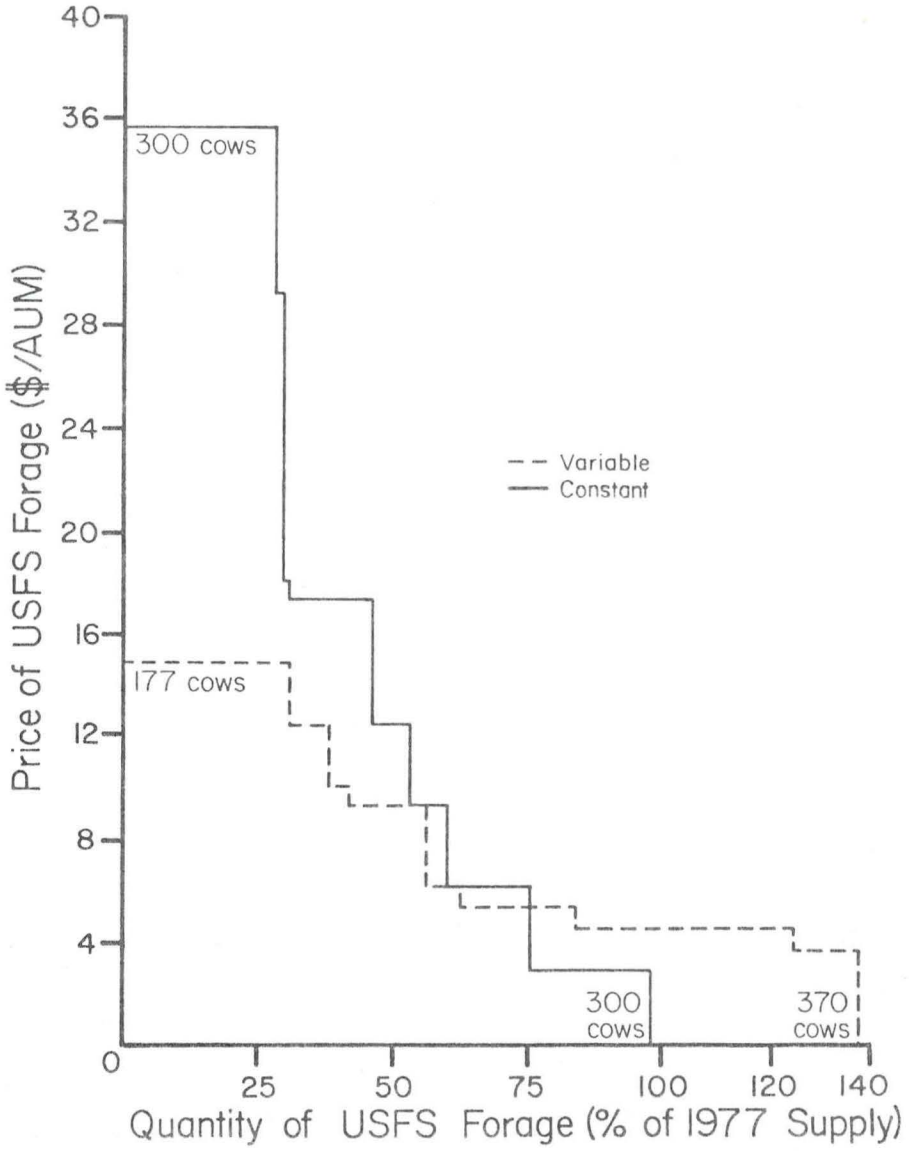

Figure 8. USFS forage demand for a mid-sized model ranch in southwestern Colorado for the two management schemes and average livestock prices.

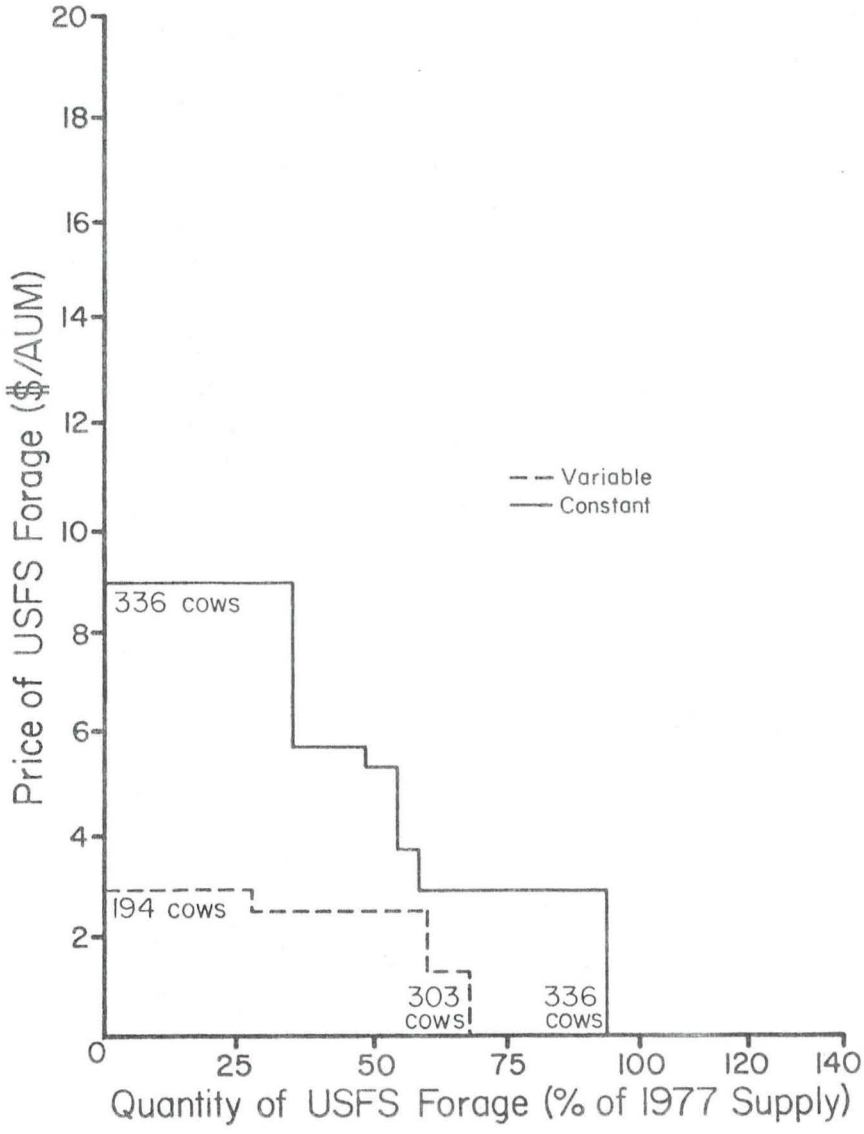

Figure 9. USFS forage demand for Northwest Cattle Model 3 for the two management schemes and low livestock prices.

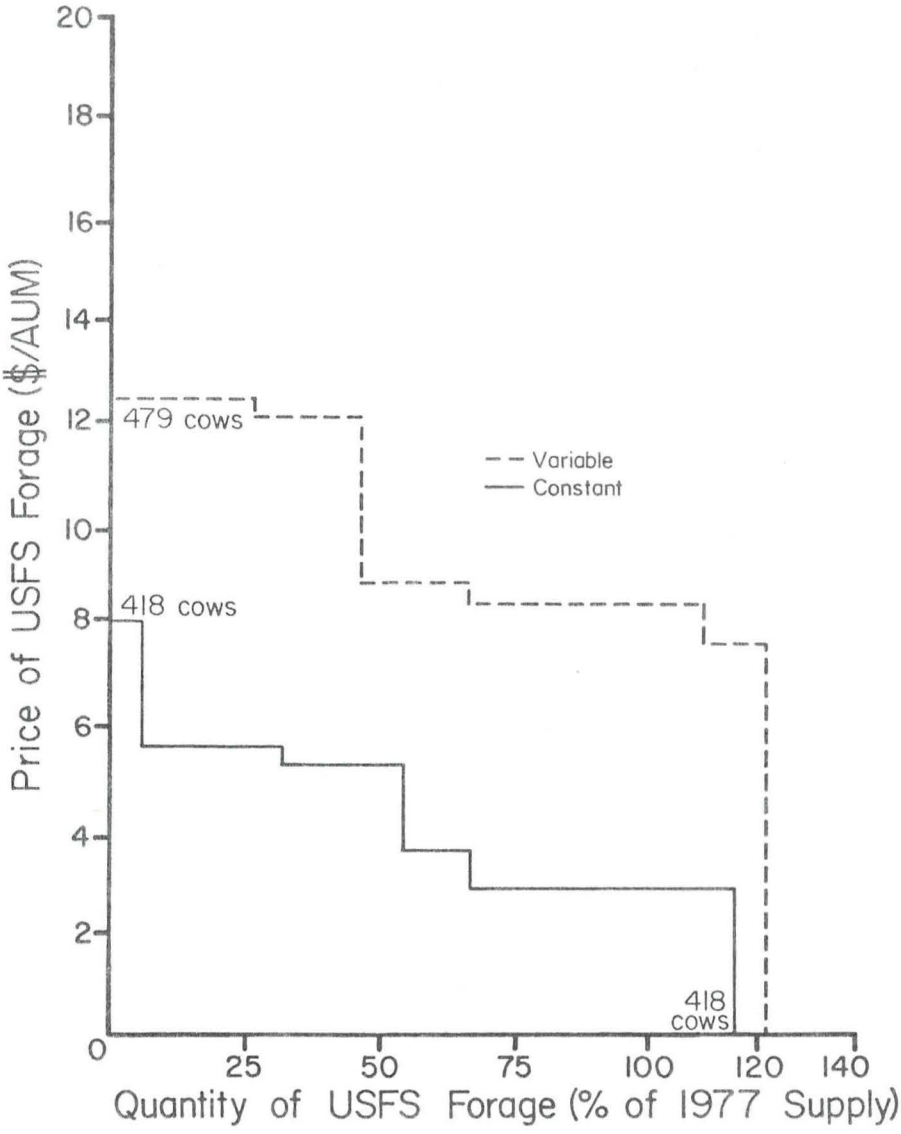

Figure 10. USFS forage demand for a large model ranch in southeastern Colorado for the two management schemes and high livestock prices.

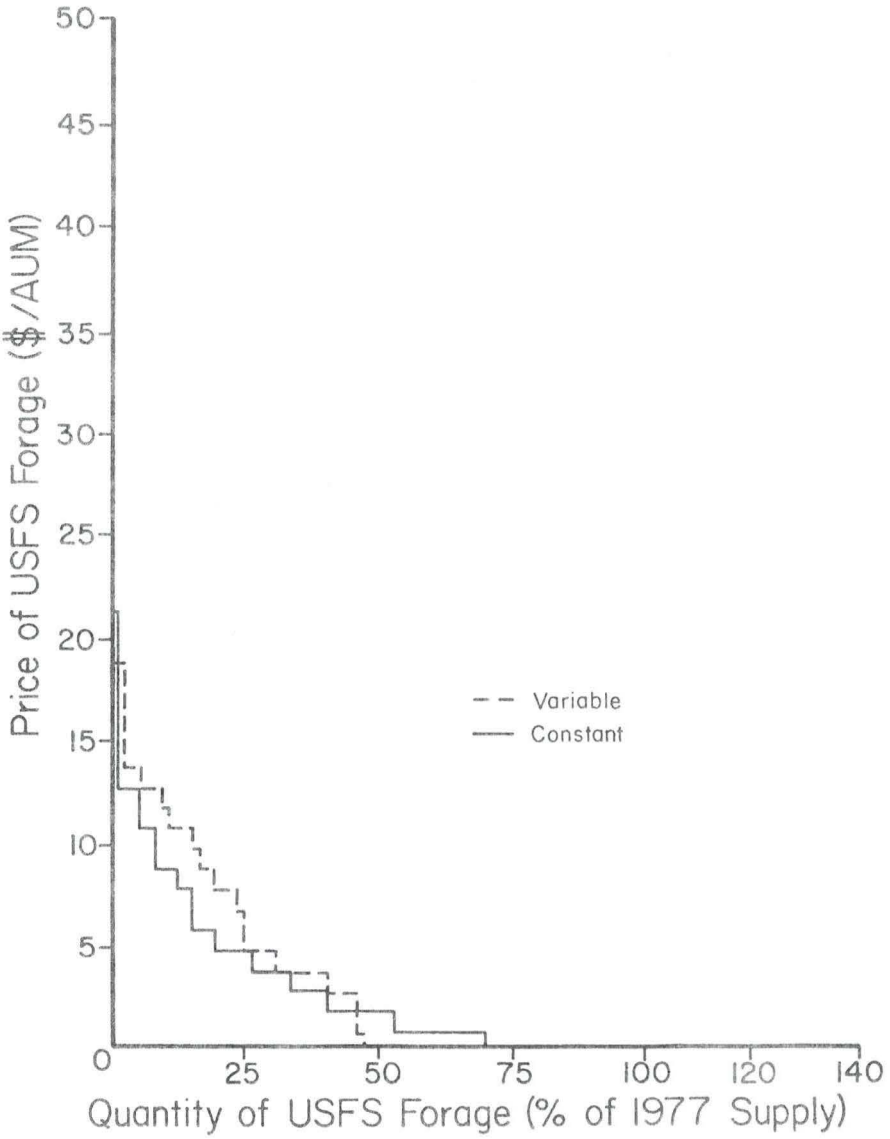

Figure 11. Aggregated USFS forage demand for Colorado for the two management schemes and low livestock prices.

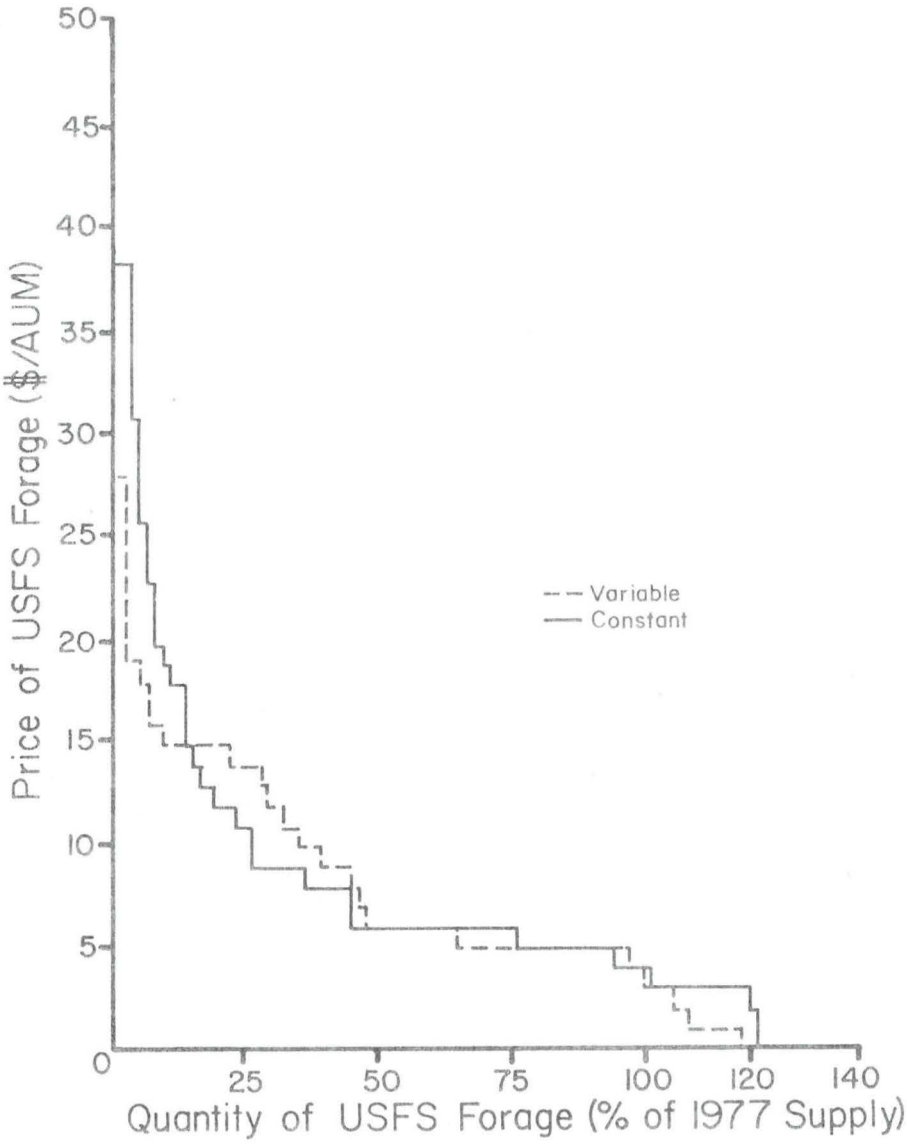

Figure 12. Aggregated USFS forage demand for Colorado for the two management schemes and average livestock prices.

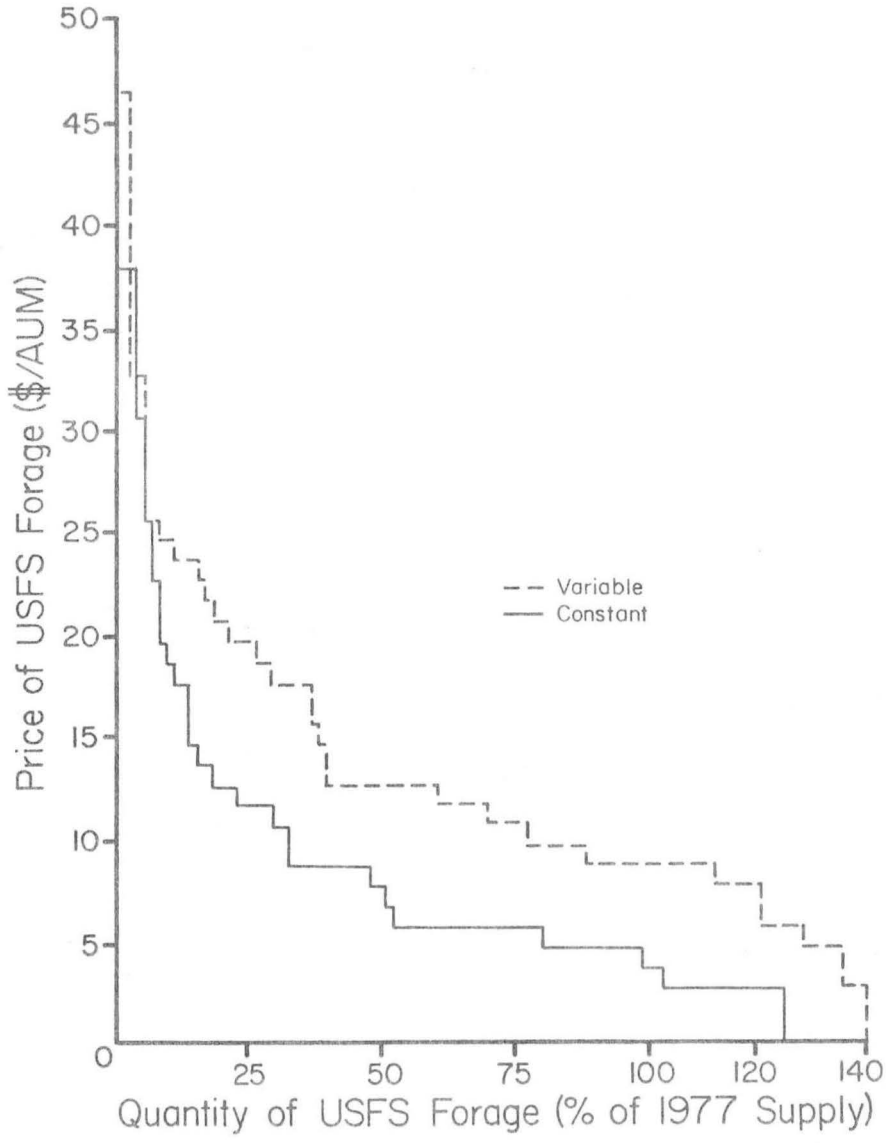

Figure 13. Aggregated USFS forage demand for Colorado for the two management schemes and high livestock prices.

As seen in Figure 11 the herd size vary and herd size constant curves at low livestock prices are nearly identical. This is due to the fact that in both cases eight ranches did not operate and many of the remaining 17 operated in a restricted manner. This similar decrease in the operation of ranches overshadowed any effects of the different herd management schemes.

At average livestock prices (Figure 12), the two curves are nearly identical as well. This indicates that on a state average nearly the same size herd was run in both scenarios. This is significant when it is remembered that the herd size constant scenario runs the number of livestock reported in the 1977 survey, and the herd size vary scenario runs the profit maximizing number of livestock under a given set of conditions. This means that in 1977 the number of livestock that the sample ranches were running was very nearly the number that would, on the average, have made the maximum profit during the 1969-1979 cattle cycle. Table 18 compares prices the ranches were actually receiving in 1977 with the average price during the cattle cycle that lasted from 1969-1979. Also included are the prices for 1976 and 1978 to show the variability in prices that the sample ranches faced.

It has been shown that the herd size vary scheme is able to capitalize on high livestock prices, while the herd size constant scheme is unable to. High livestock prices are accompanied by herd expansion and an increase in the demand for USFS forage. This increase in demand is shown clearly in Figure 13. It must be remembered that on individual ranches it is often difficult to adjust animal numbers in the short-run.

Table 18. Livestock selling prices in selected years.

Livestock class	Selling price[1] ($/cut)			
	1976	1977	1978	1969-1979 average
Calves	39.81	42.10	69.20	57.27
Yearlings and stockers	36.79	40.53	62.69	52.04
Cull cows	21.93	24.70	40.59	32.19
Lambs	46.31	52.70	58.70	48.52
Cull ewes	15.97	13.00	25.08	14.03

[1]Adjusted to 1977 prices.